EUROPA: CHAOS TERRAINS FORMATION AND ITS EXOBIOLOGICAL POTENTIAL. M. Glamoclija and G. Mitri, Int'l Research School of Planetary Sci.,University of G.d'Annunzio, Italy (Viale Pindaro 42, 62127 Pescara, Italy, mihaelag@irsps.unich.it, mitri@irsps.unich.it),

Introduction: Processes and conditions of Europa's crust support assumptions about habitability of this icy satellite. A combined ice/liquid water shell ~80-170 km thick is indicated by Galileo space craft gravity measurements [1], this ice shell has undergone through geological resurfacing in a time period of ~10 million of years [2]. Different models predict tidal heating strong enough to maintain a global subsurface ocean of liquid water [3] and geothermal activity sufficient to cause regional melting of icy lithosphere [4, 5]. Features like chaotic terrains might be formed by this kind of processes [6], which will involve mixing of subsurface liquid water with ice material from surface. With cover of 40% of Europa's surface, obvious mixing of water and ice and past presence of thermal activity, the chaotic terrains present area where we should look for habitable zones of Europa.

Geophysical background: Thermal activity on the sea floor can be the cause of the origin of the chaotic terrains. Previous models predicted global periodic thermal activities of rocky interior can occur within a period of ~10^8 years [9]. We have estimated that for a minimum increasing of water temperature of 1^0C, a time period of $7x10^4$ years is necessary [6]. This rate of changes in the temperature will cause significant melting of the ice shell. Such a global changes are probably followed by opening of regional vents on the purported ocean floor. Formation of chaotic terrains is more likely the result of internal regional processes driven by thermal perturbations. According to the thermodynamical model we used, ~3.5 km thick icy shell can be melt in 10^6-10^8 years [6]. This means that during this period emissions from the sea floor would be active, and create a stable and warm environment on the ocean floor. This warm environment can be extended to the circulating water column above. Convective currents may produce mixing of water from upper layer enriched in H_2O_2, H_2SO_4, CO_2 [7] with deep ocean water. Chaos-forming thermal processes leads to formation of lateral cracking and migration of rafts [4]. Due to the very low temperature (~110 K) on the surface, in areas of cracking and mixing of ice and water, is possible that the liquid water is not directly exposed to the surface, and forming slush. This could shield biocommunities in water from outer radiation influence.

Exobiological potential: Due to high ultraviolet radiation and radiolysis by charged particles on Europa's surface we can not expect to find habitable environment. However the surface is rich in elements which are biologically important. The NIMS instrument on board Galileo spacecraft found evidence for H_2O_2, H_2SO_4, CO_2 compounds on the surface of Europa [7]. These coumpounds can provide oxygen necessary to the living microrganism. Organic functional groups C-H and C≡N have been detected on other icy satellites (such as Ganymede and Callisto) and there are some hints of their presence on Europa, too [8]. Furthermore, important quantities of sulfur and other materials are possible to be continuously ejected from Io to Europa [7]. The water on Europa appears to contain highly soluble salts such as NaCl, Mg and Na sulfates and sulfate hydrates [7, 12]. Mixing of ocean water with these elements which are present only at the surface of the satellite is necessary for development and survival of any possible Europan ecosystem.

Methanogenesis might have been one of the earliest sources of metabolic energy on Earth, and is the largest source of chemical energy that does not required dissolved O_2 or SO_4^{2-} . All methanogens cultured from Earth are aerobic thermophiles, with optimum growth temperature 2-40^0C [13].

Methanogenesis is most probable source of metabolic energy in Europa's ocean environment, too (due to conversion of CO_2 and H_2 in methane). Minimum requirements to get conditions suitable for reactions of methanogenesis are: ocean with relatively reducing conditions and temperature >6.5^0C [13, 14], or ocean with oxidizing condition but in this case you need higher temperatures to sustain the biocommunity.

We found a minimum water temperature of 10^0C for starting methanogenesis to provide enough energy for metabolism in both reducing or oxidizing ocean environments. Considering this temperature threshold, 1.1 x 10^6 years are required to completely melt the icy shell. Within this time, mixing of chemical elements from surface with ocean water will be possible. Also, pressure of water layer makes important influence on life conditions. In case of Earth, we know that extreme barophilic bacteria have optimum growth at 50 MPa and they are able to grow under 100 MPa [14]. The highest pressure value under which extremes were isolated on Earth is 110 MPa [14]. In that case we have considered as desirable pressure what life forms can survive in range 50-110 MPa, what correspond with depth range 3.8–84 km (with density of water layer ~1000 kg/m^3) of Europan ocean, also chemical processes of methanogenesis are stable in this pressure range. In this way we are able to fulfill minimum requiments for starting methanogenic processes and conditions necessary for life to survive.

Cold temperature from the surface will cause freezing process, so if we take into account a time range for closing the cracks in the chaotic terrains (in case that we consider refreezing block of 0.3 to 2 km thickness [15]) in 800 – 3.6 x 10^4 years we will have optimum time sequence. This kind of process can provide stable environment for a period of time long enough to develop and sustain stable life conditions, and eventually to diversify and stabilize biocenose.

During the period of refreezing some microorganisms may remain trapped in the new ice.

Earth investigation of glacial ice at Vostok Station, Antarctica etc. reveal that viable cells and nucleic acids may remain preserved for hundreds of thousand of years in glacial ice as dormant or entrapped microbes[10]. In this way, they would have good chances to be liberated later with a new melt event. All organisms will not be entrapped in ice, so the others would probable use currents (tidal and convective currents) to find another suitable environment.

Beside the possibility to find preserved life in newly made ice within the thin icy crust cracked due to process of melting, there is possibility of clathrates creation as possible habitable zones.

On Earth complex faulting systems and slide structures in ice are common, clathrates are usually created around sites of hydrocarbon fluid venting in some areas of the deep cold ocean floors [11]. On Europa free hydrocarbon gases or hydrate phases could be trapped at lower surfaces of the icy crust in anticlinal structures created by faulting within crust or by icy plutons. Clathrates can absorb gases which are too volatile to condense, like CH_4, CO, N_2 etc. [12]. That types of gases are important biological nutrients and their concentration can provide oases for possible biocommunities cope with Europa's harsh conditions.

Final remarks: Following our new calculations on the thermal stability of the upper icy crust of Europa, we have determined an average ice thickness of ~3.5km and an estimation of the time necessary for a complete melting of the crust (~10^6-10^8 years). We have started to develope an exobiological model based on the thermal evolution of the icy crust. We selected that the minimum requiments for starting methanogenesis which is one of the most favourable process for having life in this harsh environment, are 10^0C and 50-110 MPa. These parameters are consistent with the observations of the Europa surface as suggested by thermal conditions to form the chaotic terrain.

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